



# **PLANS FOR MINIATURE MACHINING AT LASL**

**by**

**Richard Rhorer  
Los Alamos Scientific Laboratory**

## **ABSTRACT**

A special shop for making miniature or very small parts is being established within the LASL Shop Department, and one of the machine tools for this shop is a high precision lathe. This report describes a method based on scale modeling analysis which was used to define the specific requirements for this lathe.

## PLANS FOR MINIATURE MACHINING AT LASL

by

R. L. Rhorer  
Los Alamos Scientific Laboratory

For the last couple of years the LASL Shop Department has considered establishing a shop to make very small parts, or a "miniature shop". We are now proceeding with setting up this miniature shop, primarily with machine tools and equipment already at LASL, but previously located in several shops. Much of the work we intend for this shop is not particularly a new type of work, but we hope to improve our efficiency and turnaround time on the turning and drilling or diameters down to a few mils size.

Some of our miniature work is an outgrowth of "target" fabrication for inertial confinement fusion; however, many of our miniature machining needs are for other research projects, and usually require only one or two of each part on a short turnaround. In addition, we may establish a shop primarily for target fabrication in the near future. Our miniature shop may support this target fabrication facility with development or research in machining techniques. The miniature shop will draw on some of the experience of our precision or diamond turning efforts.

Some of the details and possible tools required for this miniature shop are listed in Fig. 1. Many other items such as microscopes, surface plates, inspection equipment, etc. may be necessary, but this is a summary of our initial plans for the shop. The need for a 2 axis NC lathe was established. Presented in Fig. 2 are some more details on the Pneumo lathe we have ordered for this job.

To arrive at these requirements which eventually resulted in us ordering a Pneumo lathe, a simple scale model analysis was performed. Scale modeling is usually used to build a small model of a large system, make measurements or do experiments on the model, and then predict the performance of the larger or prototype system. The method used to design such a model is illustrated in Fig. 3.

This deals with geometric similarity only, but other variables such as, time, velocity, force, stiffness, etc., also need to be scaled, (often not as simple as geometry, but a scale relationship can be found) to satisfy "complete similarity" between model and prototype. Any variable that affects the performance or response of this system has to be scaled.

To help answer the questions of "what kind of machine is needed to make small parts?" We looked at the requirements from the stand-point of scale modeling. A slightly different approach than normal was used. In this case the prototype or "real" system is a very small part, and a model was chosen of conventional size part. Such a case is illustrated with an example in Fig. 4.

A typical miniature part was chosen for the example. From scale modeling relationships a conventional size part 100 times larger was designed as a model. The machine requirements to make this model were then determined from conventional machining experience. Then using this information and scale factors, the machine requirements for the miniature machine were determined.

The results indicate a machine with positioning accuracy of  $0.1\text{ }\mu\text{m}$  and a spindle runout of  $0.02\text{ }\mu\text{m}$  is required. These type accuracies are currently found only in large state-of-the-art machine tools, not jewelers type lathes.

The small cutting force (.001 N) for the miniature part dictates the use of displacement control rather than a force sensitive or "feel" type operation. Therefore, a machine with high quality closed-loop displacement control is indicated.

To produce the surface finish required for the miniature part, special concern for vibration isolation is also needed. The criteria for evaluating vibration in a machine is determined from scale model analysis; namely, random displacements between the work and tool must be less than 100 times smaller for the miniature machine.

The type of scale modeling used for this study requires that the velocity scale factor be unity. Therefore, as shown, the spindle RPM becomes quite high for complete similarity between the model and prototype. This high RPM may not be practical, but the effect of a lower cutting speed can be examined from other scale factors.

The primary conclusion of this study was that if we want to make small parts that look as good under a microscope as conventional parts do without magnification, then we need the best machine possible for making the small parts; therefore, we are purchasing a diamond turning quality machine.

**Fig. 1 SHOP FOR MINIATURE MACHINING**

**Approximately 1800 sq. ft. - semi-clean room**

**Probably contain:**

**3 Hardinge Tool Room Lathes  
3 Jeweler's Lathes  
Najet Drill  
Tsugami Grinder  
Small Swiss Automatic Lathe  
Small Jig Bore  
2-Axis CNC Lathe**

**Fig. 2 2-AXIS CNC LATHE FOR MINIATURE WORK**

**Pneumo Precision, Inc. - Model MSG-325**

**X-Travel - 12 inch**

**Z-Travel - 8 inch**

**Air Bearing Ways**

**Air Bearing Spindle**

**Swing - ~ 14 inch**

**Resolution - 10 microinch**

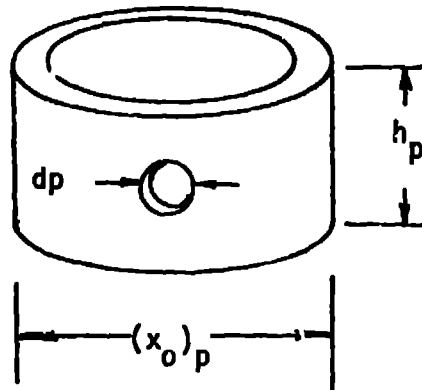
**Controller - Allen-Bradley 7360**

**Laser Interferometer Feedback (HP5501)**

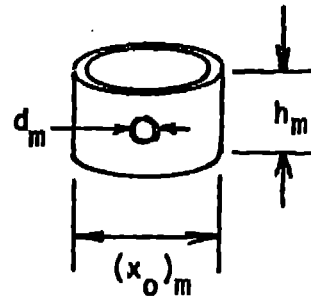
**Approximate Cost \$210K + ~ \$90K**

**Fig. 3 SCALE MODELING**

**Geometry Similarity**



**Prototype System (p)**



**Model System (m)**

The dimensions of the prototype and model are related as:

$$\left\{ \frac{h}{x_o} \right\}_p = \left\{ \frac{h}{x_o} \right\}_m .$$

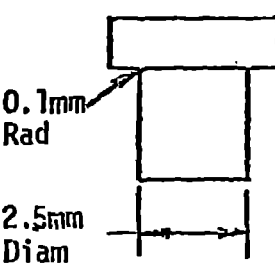
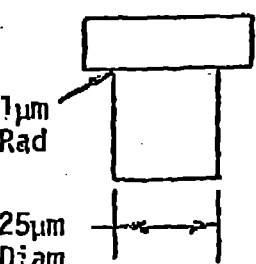
and,

$$\left\{ \frac{d}{x_o} \right\}_p = \left\{ \frac{d}{x_o} \right\}_m .$$

All other dimensions are related in a similar manner, and the length scale factor is:

$$\text{SCALE FACTOR } N_L = \frac{(x_o)_p}{(x_o)_m}$$

Fig. 4 - SCALE MODEL RELATIONSHIPS

	MODEL (CONVENTIONAL PART)	VARIABLE AND SCALE RELATIONSHIP	PROTOTYPE (ICF SIZE PART)
PART DIMENSIONS	 <p>0.1mm Rad</p> <p>2.5mm Diam</p> <p>Tolerance <math>\pm 0.1\text{mm}</math> Surface finish <math>1\mu\text{m RMS}</math></p>	<p>Dimensions Length Scale <math>N_L = 0.01</math></p> <p><math>\frac{\text{Length in Proto}}{\text{Length in Model}} = 0.01</math></p> <p>(Applies to all Dimensions)</p>	 <p>1μm Rad</p> <p>25μm Diam</p> <p>Tolerance <math>\pm 1\mu\text{m}</math> Surface finish <math>0.1\mu\text{m RMS}</math></p>
SOME MACHINE PARAMETERS	0.1 mm	Tool Radius ( $N_L = .01$ )	1 μm
	2 μm	Spindle Runout ( $N_L = .01$ )	0.02 μm
	$\pm 10 \mu\text{m}$	Position Accuracy ( $N_L = .01$ )	$\pm 0.1 \mu\text{m}$
	1000 RPM (131 mm/sec)	Spindle Speed (Velocity, $N_V = 1$ )	100000 RPM (131 mm/sec)
	Approx. 10 Newtons	Cutting Force <sub>2</sub> (Force, $N_F = N_L^2 = .0001$ )	0.001 Newtons